The importance of measuring lower limb cumulative load in sport: a mechanobiological approach

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I. Introduction

MUSCULOSKELETAL tissues, such as bone, muscle, tendon and cartilage, respond and adapt to their local mechanical environment in such a manner as to maintain a stable equilibrium, or homeostasis. Knowledge of how an individuals tissue responds and adapts to stress is critical to design training interventions to maximise performance gains and minimize risk of injury.

Given an appropriate loading stimulus and sufficient rest and recovery, musculoskeletal tissue will adapt positively to load. However, an inappropriate load or lack of recovery can also result in injury. Lower limb musculoskeletal injuries are common in sport and all have a mechanical aetiology, either via acute mechanisms (e.g. single impact event) or via repetitive, chronic mechanisms (e.g. fatigue fracture or tendinopathy).

II. Objective

Our ultimate goal is to provide coaches, players, and training staff with easy-to-use field-based sensors that can accurately measure and monitor the acute and chronic loading experienced by the musculoskeletal system.

III. Discussion

The terms 'acute' and 'chronic' have also been used to describe bouts of training, where the ratio of acute:chronic workload has been shown to be predictive of performance gains and injury risk [1]. In this context, workload was determined using a torso-mounted global positioning system (GPS) (to measure speed and distance traveled) and a surrogate measure of player load using a tri-axial accelerometer (i.e. to measure step count). While informative, GPS data and accelerations of the torso may not be effective in monitoring loads of the lower extremities, as distance and speed traveled do not represent the mechanical load experienced by the musculoskeletal tissue. This is particularly relevant in small-space game situations, or sports such as basketball, where players can experience high loads by performing explosive jumping and landing activities, which are not captured by distance, speed, or torso accelerations.

Accelerometers placed on the tibia allow for the measurement of tibial shock, or peak impact accelerations, which can function as a surrogate measure of the loads experienced by the underlying musculoskeletal tissue [2,3]. This simple, non-invasive method has been used across studies looking at impacts in landing, running, and walking tasks [3,4]. I Measure U captures these impact events from two synchronized sensors at 1000 Hz (frames/sec), thus providing accurate measurement of the impact loading placed on both limbs.

In order to adequately identify cumulative lower limb load, an appropriate metric is required which takes in to account the association between the musculoskeletal tissue and mechanical load (i.e. a mechanobiological approach). The daily load stimulus (DLS), is a metric of cumulative load which describes the relationship between mechanical load stimuli and skeletal tissue remodeling as a function of the stimulus [6]. The DLS is the product of the magnitude of the loads and the number of load cycles (or frequency) of these loads.

$$DailyLoadStimulus = \left[\sum(\sigma)^m(n)\right]^{1/m}$$

σ is the effective stress (peak loads from accelerometer)
n is the number of loading cycles
m a weighting factor

The load magnitudes are weighted by an exponential component, m, to account for the greater influence the magnitude of the strain has on skeletal tissue relative to the impact of the frequency/number of load cycles [6]. The sum of all of the products of the varying loads and their cycles provides a total load stimulus, or cumulative load. This mechanobiology concept has been used to model bone remodeling and can also be applied to other skeletal tissue (e.g. cartilage and tendon). By integrating our sensor technology with this mechanobiological perspective of tissue adaptation, we have the tools to accurately measure and monitor the mechanical workload of an individual athlete.

References

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